

MASSACHUSETTS INSTITUTE OF TECHNOLOGY  
Department of Physics

Physics 8.01X

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## PRACTICE EXAM 1 SOLUTIONS

1a) Yes, the scale does change its reading when the person is in the air inside the box. The person, in free fall, exerts no forces on the floor or the walls of the box. This contrasts with the situation when the person is standing on the floor of the box. The floor of the box transmits the downward force from the weight of the person to the scale and this is balanced by an upward force from the scale in response.

1b) No, there is no difference in the reading on the scale depending on whether or not the hummingbird is resting on the floor of the box or hovering within the box. In both cases, the weight of the hummingbird is supported by the box which transmits the force of this weight to the scale. When the hummingbird is hovering, the force of its weight is countered by the force of air pressure underneath its wings. This air presses down on the box in a fashion that transmits the force of the weight of the hummingbird to the box.

2) First, find the time that the football stays in the air. Do this by determining when the y position of the football is zero. The initial velocity of the football in the y direction is  $v_0 \sin \theta$ .

$$y = 0 = (v_0 \sin \theta) \cdot t - \frac{1}{2} g t^2$$

Solving this, we find that the find that the football stays in the air for a time given by:

$$t = \frac{2v_0 \sin \theta}{g}.$$

The x velocity of the football remains unchanged at  $v_0 \cos \theta$ , so during the time that the football is in the air, it travels a distance:

$$x = \frac{2v_0 \sin \theta \cos \theta}{g} \text{ or, simplifying this formula: } x = \frac{v_0 \sin 2\theta}{g}.$$

On the first kick, the ball travels a known distance  $x_1 = \frac{v_0 \sin 2\theta_1}{g}$ . On the second kick, it

travels an unknown distance  $x_2 = \frac{v_0 \sin 2\theta_2}{g}$ . In each case,  $v_0$  is the same value. To find

$x_2$ , we simply divide the second equation by the first equation and then multiply by  $x_1$ .

This gives:  $x_2 = x_1 \frac{\sin 2\theta_2}{\sin 2\theta_1}$ . We know all the quantities on the right hand side of this equation. Plugging in the numbers, we find that  $x_2 = 69.2$  yards.

3a) At small times we can expand the exponent in a Taylor series. The first four terms of this series are:  $1 - \frac{t}{RC} + \frac{1}{2} \left( \frac{t}{RC} \right)^2 - \frac{1}{6} \left( \frac{t}{RC} \right)^3 + \dots$ . At small times,  $\frac{t}{RC} \ll 1$ , and we can safely ignore all but the first two terms.

Therefore at small times, equation 1) becomes:  $V_{cap}(t) \approx V_{cell} \left( -\frac{t}{RC} \right)$ . Flipping this around, we find that  $t \approx \frac{RC}{V_{cell}} V_{cap}(t)$ .

3b) For this, we need  $\frac{t}{RC} = 0.2$ . Plugging in the numbers gives  $t = 4$  seconds.

3c) Using the equation  $t \approx \frac{RC}{V_{cell}} V_{cap}(t)$ , we can determine the times for falling each of the distances. The formula  $y = \frac{1}{2} g t^2$  tells us that if we plot the distance of each fall as a function square of the time for the fall, the slope on the plot will be  $\frac{1}{2} g$ . For the three distances, we find squared times of  $0.0524 \text{ sec}^2$ ,  $0.0267 \text{ sec}^2$ , and  $0.0139 \text{ sec}^2$  for the three heights. Plotting these points and fitting the best straight line through these points (the line must also go through zero, because we expect that for zero height it takes zero time to fall!), we get the plot below.

The slope of the line drawn is about  $0.495 \text{ meters/second}^2$ . Our measured value for  $g$  is  $9.81 \text{ m/s}^2$ .

